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G Anil Kumar Reddy
M.Sc. Research Scholar,
Department of Agronomy,
School of Agriculture, Lovely
Professional University,
Jalandhar, Punjab, India

Dr. Chandra Mohan Mehta
Associate Professor,
Department of Agronomy,
School of Agriculture, Lovely
Professional University,
Jalandhar, Punjab, India

Corresponding Author:
G Anil Kumar Reddy
M.Sc. Research Scholar,
Department of Agronomy,
School of Agriculture, Lovely
Professional University,
Jalandhar, Punjab, India

Crop residue management: A solution to *in-situ* residue burning: A review

G Anil Kumar Reddy and Dr. Chandra Mohan Mehta

Abstract

Crop residue is the stuff that remains in the field after crop harvesting and includes leaves, stems, stalks, stubble, pods and so on. Crop residue is a valuable input component for achieving sustainable agriculture because it improves the physicochemical and biotic properties of soil, increases soil fertility, and thereby increases crop productivity. In India, 500 million tonnes of crop residues are generated every year in which rice crop has major part. Farmers burn crop residue to clear fields for succession crops as cost effective method although government is making awareness programs about alternative purpose and restrictions on burning due to the adverse impact they have on the environment. Crop residue incorporation and crop residue retention are two other viable of options crop residue management that include using a portion of surplus residue. Crop residue management can enrich soil fertility and crop yields by sustaining soil organic matter. Crop residue management practices are the most important approach among the nutrient balance approaches. Straw is an asset, not a liability. The review highlights the importance of *in-situ* crop residue application through crop residue management.

Keywords: crop residue, burning, rice straw, residue management

Introduction

India produces more than 500 million tonnes of crop residues each year owing to its agricultural dominance. Uttar Pradesh followed by Punjab and Maharashtra creates maximum crop residues. In figure 1 comparison of agriculture waste production of India with some Asian countries. (Bhuvaneshwari *et al*., 2019) [4]. The majority of these agricultural leftovers are burned on the fields to clear left-over straw and stubbles after harvest, which interfere with the tillage and seeding operation of succeeding crop. Bisen & Rahangdale (2017) [7]. In Northwest India, agricultural residue burning has an influence on human and animal health, both medically and through traumatic traffic accidents caused by reduced visibility. The yearly burning of rice leftovers in nearby fields coincided with a high in the number of asthmatic patients in hospitals in Northwest India. Kumari *et al*., (2019) [17]. Owing to a lack of human labour, the high cost of clearing crop residues using traditional techniques and the use of combines for crop processing, the issue of on-field burning of crop residues has become worse in recent years. IARI (2012) [12]. In figure 2 State-wise details of crop residue generated, residue surplus and crop residue burned. Rice, wheat, sugarcane, millets, cotton, jute, maize, groundnut and rapeseed-mustard residues are commonly burned on farms throughout the nation. In figure 3 total crop residue and available crop residue of most important crops of India. Thakur & Gudade (2018) [35]. Out of total crop residue production, more than 2/3rd comes from wheat (24.02%), rice (23.61%), and sugarcane (22.77%) and less than 1/3rd from other crops (figure 4). From the perspective of the farmers, burning rice straw may be the most appropriate way of disposal. It is not only a cost-effective tool, but it also works as a pest control method. Kaur *et al*., (2019) [15].

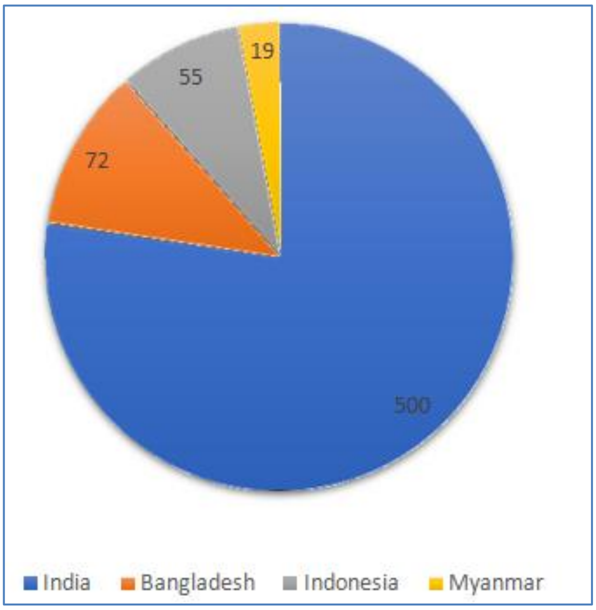
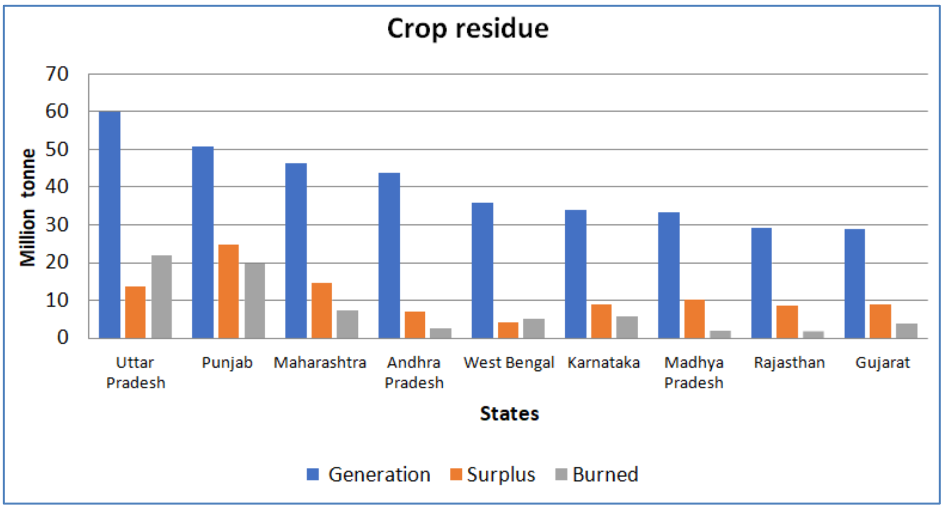
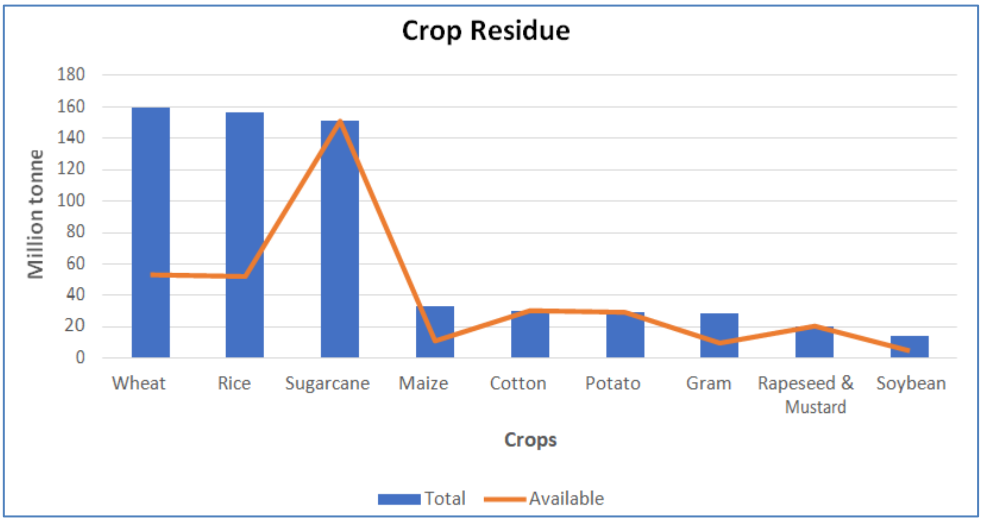


Fig 1: Comparison of agriculture residue generation (million tons/year) among some Asian countries. Bhuvaneshwari *et al.*, (2019) [4]



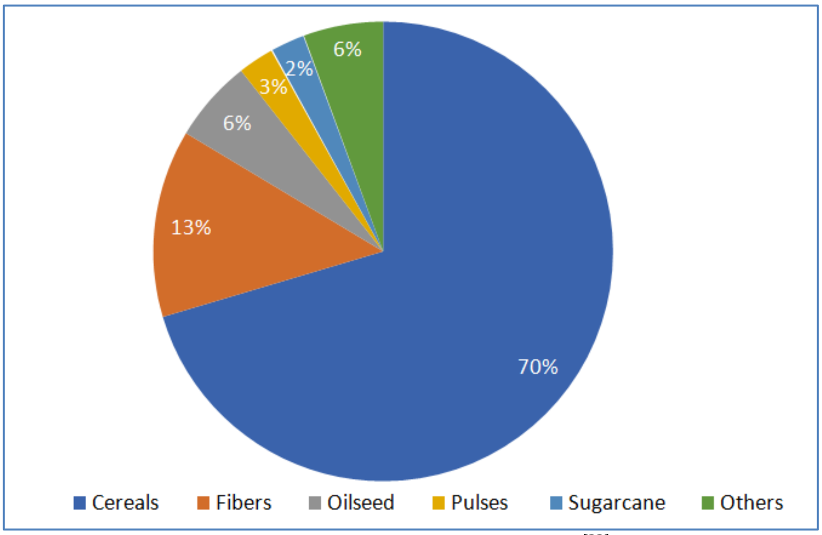
Source: National Policy for Management of Crop Residues (NPMCR).

Fig 2: State-wise details of crop residue generated, residue surplus and crop residue burned.



Source: Thakur & Gudade (2018) [35].

Fig 3: Total crop residue and available crop residuDe of most important crops of India



Source: MOEF (ministry of enzironment and forest) 2018 [22]

Fig 4: Crop residue generation among different groups of crops

Wheat and rice both are intensive feeders of nutrients and due to this excessive nutrient mining of soils is one of the foremost reason of poor soil health under the rice-wheat growing areas. Rice and wheat lose more nutrients than are applied by fertilizers and recycled. Bisen & Rahangdale (2017) [7]. Rice-wheat cropping system production in the Indo-Gangetic plains is plateauing due to over-exploitation of environmental assets. Jat *et al*., (2020) [13]. The rice-wheat cropping system is the world's biggest agricultural production cycle, covering about 12.3 million hectares in India, 0.5 million hectares in Nepal, 2.2 million hectares in Pakistan, and 0.8 million hectares in Bangladesh, with about 85 percent of this region falling within the Indo- Gangetic plains. Bhatt *et al*., (2016) [3]. Rice straw is grown at a global scale of 800 to 1,000 million tonnes per year, with around 600 to 800 million tonnes produced in Asia. Anonymous (1) [1].

The rice crop residue is burned *in-situ*, which is a traditional management procedure in Punjab, Haryana, and Uttar Pradesh in north-western India. In Maharashtra, West Bengal, Bihar, Tamil Nadu, Jammu & Kashmir, Assam and Gujarat it is used as cattle fodder, thatching for rural dwellings, fuel for household cooking and industries, mulching soil, compost manufacturing, power production, biofuels, and in boilers for parboiling paddy. (Lohan *et al*., 2018) [19]. Each kilogramme of milled rice yields 0.7–1.4 kg of rice straw, depending on the variety, stubble cutting height, and moisture content after harvest. After the plants have been threshed manually with stationary threshers or, more recently, using combine harvesters, the rice straw is separated from the grains. The open burning of rice residues results in the loss of important nutrients as well as the production of harmful gases such as hydrocarbons, carbon monoxide, volatile organic compounds, and inhalable particulates. Tariq *et al* (2017) [34]. In table 1 Emission of important pollutants from crop residue burning (Gg/year) in 2017-2018. Venkatramanan *et al*., (2021) [38]. Soil quality is deteriorating at an unprecedented pace, resulting in macro and micronutrient shortages in the nation's soils. Bhatt *et al*., (2016) [3]. Tillage and crop residue management are crucial in preserving the physical and chemical properties of the soil, which in turn influence crop productivity. Singh *et al*., (2018) [31]. Rice straw is used based on its qualities, which are categorised into three categories: physical qualities (bulk density, heat capacity, and thermal conductivity), thermal properties (heat capacity), and chemical composition (lignin, cellulose, hemicellulose and nutrient content). are applicable to a variety of uses, including animal feed and soil fertility. Van *et al*., (2020) [36]. Bisen & Rahangdale (2017) [7]. Reported that for three years, a rice straw application of 16 t ha-1 reduced bulk density in the 0-5 cm layer of a sandy loam from 1.20 to 0.98 g cm-3.

In Punjab, rice cultivation expanded from 0.29 million hectares in 1965-66 to 2.97 million hectares in 2015-2016. (Anonymous (2) [2]. Punjab's major planting pattern is rice-wheat. In Punjab, these crops produce 51 Mt of agricultural residue. The rice crop residue was expected to be 22.9 million tonnes, while the wheat crop residue was expected to be 23.1 million tonnes, with 95 percent of paddy straw and 23 percent of wheat straw being burned in the fields. Bimbraw, (2019) [5]. wheat residue is fed to animals and rice residue is considered unsuitable for animal feed because it contains high silica percent, hence it is often burnt by farmers. Meena (2015) [21]. However, Urea treatment of straw, which is rice straw ensilaged with 2–4% urea, can increase the rice straw's consumption and digestion as fodder. Van *et al*., (2020) [36].

Table 1: Emission of important pollutants from crop residue burning (Gg/year) in 2017-2018.

Crops	CO2	CH4	N2O	BC	NMVOC	SO2
Rice	49,601.10	88.398	2.29	22.59	229.18	13.09
Wheat	50,949	90.8	2.35	23.2	235.41	13.45
Sugarcane	45,571.20	81.21	2.1	20.75	210.56	12.03
Cotton	4,561.66	8.12	0.21	2.07	21.07	1.2
Jute and Mesta	1,472.58	2.62	0.06	0.67	6.8	0.38

Source: Venkatramanan *et al.*, (2021) [38]

Crop residue burning

Rice straw burning in open fields has well-known detrimental environmental and agronomic consequences due to air pollution and lowered soil quality. Table (2). After straw burning, the temperature of 7 cm topsoil increases. Bimbraw, (2019) [5]. Since rice straw has little economic value and labour is scarce, farmers are hesitant to engage in the field cleaning with a chopper. This procedure necessitates another procedure, which raises the rate. Farmers in north-western India have learned that burning is the cheapest and easiest way to remove enormous amounts of rice leftovers so that the wheat crop may be established quickly following rice. Farmers currently burn more than 80% of total rice straw generated annually in three to four weeks in October and November. Singh & Sidhu (2014) [27]. Burning rice residue pollutes the environment and contributes to global warming by emitting greenhouse gases such as nitrous oxide, methane, and carbon dioxide, as well as lowering organic matter amounts, killing beneficial insects, degrading the soil, creating a net negative nutritional balance, and thereby deteriorating soil quality. (Bhatt *et al*., 2016 [3]; Romasanta *et al*., 2017 [26]). It is projected that burning one tonne of rice straw results in the loss of 5.5 kg of nitrogen, 2.3 kg of phosphorus, 25 kg of potassium, and 1.2 kilogramme of sulphur, in addition to organic carbon. Burning removes around 80– 90% of the nitrogen, 25% of the phosphorus, 20% of the potassium, and 50% of the sulphur contained in agricultural residues in the form of different gaseous and particulate materials. Thakur and gudade (2018) [35]. However, Rice straw burning in the open field effectively destroys vast amounts of biomass and aids in the management of weeds, rodents, and diseases. Ponnamperuma (1984). Vats (2015) [25, 37]. Reported Burning crop residues may enhance phosphate and potassium availability, resulting in the eradication of pathogen-host for insects and diseases.

Table 2: Effect of crop residue management in a rice-wheat rotation on soil physicochemical properties over a 7-year period

Residues	pH	EC(dSm-1)	O.C (%)	Avail. N (Kg ha-1)	Avail. P (Kg ha-1)	Avail. K (Kg ha-1)
Incorporated	7.7	0.18	0.75	154	45	85
Removed	7.6	0.13	0.59	139	38	56
Burned	7.6	0.13	0.69	143	32	77

Source: Mandal *et al.*, (2004) [20]

In-situ Rice Residue Management options

Soil organic matter management on arable lands has become more significant in many parts of the globe as a means of combating land degradation, boosting food security, lowering carbo dioxide emissions, and mitigating climate change. (Parit *et al*., 2020). Crop residue incorporation and crop residue retention are two important management practices to apply residue in the field.

Crop residue incorporation

Returning crop residue to the soil improves soil quality by reducing erosion risks, improving water retention, storing/recycling nutrients, reducing soil bulk density, maintaining soil structure and improving tilth, increasing cation exchange capacity, providing energy for microbial processes, transmission properties and increasing agronomic productivity. Lal, (2005) [18]. Based on the N ratio in urea, one tonne of straw has 8 kg nitrogen, which may replace around 28 kg of urea as fertiliser. Soam *et al*., (2017) [33]. Direct drilling of wheat into combine- harvested rice fields with a standard zero till seed drill, on the other hand, has problems because of poor traction of the seed metering drive wheel due to loose straw, straw build-up in seed drill furrow openers and the need to raise the implement frequently under heavy residue conditions, resulting in uneven seed depth and thus crop establishment. Sidhu *et al*., (2015) [29]. Wheat yields were reduced for the first one to three years after rice straw incorporation 30 days before wheat planting due to soil N immobilization in the presence of crop residues with a high C:N ratio, but straw incorporation had no effect on wheat yields in subsequent years. Mandal *et al*., (2004) [20]. Ghoneim, (2012) [11]. Stated that because of the nutrients necessary to support microbial development, the incorporation of straw with a high C:N ratio may initially trap inorganic nitrogen. In this scenario, the order in which rice residue is incorporated is more essential than the amount. Crop residue incorporation in the field is advantageous in terms of recycling nutrients, but it also causes temporary immobilization of nutrients, necessitating the use of additional nitrogenous fertiliser to rectify the high C:N ratio at the time of residue incorporation. Bisen & Rahangdale (2017) [7]. Straw incorporation with a beginning dosage of nitrogen of 15-20 kg ha-1, on the other hand, improves wheat and rice yields more than burning. Bimbraw, (2019) [5]. To aid early decomposition, use a disc plough to incorporate them, then irrigate and apply a bag of urea. Jat *et al*., (2010) [14]. *In-situ* incorporation of this amount of leftover straw is not only energy-intensive, but also affluent and time-consuming. Singh *et al*., (2020) [30]. Verma and Pandey (2013) [39] Noticed that crop residue incorporation with 30% additional fertilizer achieved a higher yield of wheat in two years experimental trail of the rice-wheat cropping system. However, in intensive systems with two to three cropping rotations each year, soil incorporation is a difficulty. This is because there is not an adequate amount of time for the straw to break down, resulting in poor soil fertilisation and crop establishment. Van *et al*., (2020) [36].

Crop residue retention

Soil erosion management, soil structure preservation, temperature and soil moisture regime regulation, energy supply for soil organic matter and soil biota material conservation are some of the key advantages of crop residue retention. Lal, (2005) [18]. Residue accumulation on the soil surface seems to be a safer choice for soil conservation and preventing evaporation water losses. Bisen & Rahangdale (2017) [7]. In certain cases, keeping any or all of the residues on the surface might be the better solution. Residues steadily decompose on the field, increasing organic carbon and total nitrogen in the top 5-15 cm of soil thus preventing erosion. The use of rice straw as mulch raises the C: N ratio, which alters the balance of nitrogen mineralization and immobilization. Brar *et al*., (2010) [8]. When compared to burning, leaving residues on the surface increased soil NO3 concentration by 46%, N uptake by 29%, and yield by 37%. Mandal *et al*., (2004) [20]. Jat *et al*., (2010) [14]. found that the presence of residues on the surface raises the termite population, but termites do not affect growing crops due to their saprophytic existence and migrate deeper into the soil as soil temperatures drop in the winter. Residue cover over the surface prevents the direct impact of raindrops and reduces the chance of erosion through increasing water infiltration. Singh *et al*., (2018) [31]. When crop residues are preserved on the soil surface, they operate as a physical barrier to the establishment of weeds, reduce soil temperature, conserve soil moisture, provide organic matter, and alleviate the problem of air pollution caused by large-scale burning of straw leftovers. Kumar *et al*., (2020) [16] reported that Incorporating grain legumes and safflower with conservation tillage and rice residue retention might be a long-term method to crop strengthening in rice-fallow areas for food, nutritional, and environmental security. Chen *et al*., (2019) [9] revealed that Crop residue management options ranging from burning to field retention might save about 149.9 Tg yr-1 of carbon dioxide emissions while sequestering 24.4 Tg C yr-1 of soil organic carbon. Sarangi *et al*., (2010) [28] Reported that adding rice straw as mulch @ 5.0tonnes/ha improved growth and yield attributed to the rice-mustard cropping system in the mid-hills of the north-eastern hills region. Brar *et al*., (2010) [8] observed rice straw retained during the growth of wheat in a rice-wheat rotation, wheat yields are not reduced as much as when the straw is burned when N fertilizer is broadcast. Sah *et al*., (2014) [27] studied that Under extensive rice-wheat cropping systems, zero-tillage in combination with crop residues preservation in soil increased rice-wheat system production with positive nutrient balance and improved soil quality in terms of reduced bulk density and soil pH, increased usable P2O5 (5.8%), exchangeable K2O (7.8%), and soil OM (1.5%).

Government policies for crop residue management

1. In 2014, the Ministry of Agriculture devised a national policy for management of crop residue to reduce agriculture residue burning, with the following goals: 1. promote proper agricultural machinery. 2. Collaborate with the National Remote Sensing Agency and the Central Pollution Control Board to monitor agricultural residue management using satellite-based technology. Datta *et al*., (2017).
2. For the years 2018-19 and 2019-20, the Indian government spent Rs. 6,950 million on a project called "Agricultural mechanisation for *in-situ* management of crop residues in the states of Haryana, Punjab and Uttar Pradesh, as well as the national capital territory of Delhi." The goals are to promote *in-situ* crop residue management through retention and incorporation into the soil, as well as Farm Machinery Banks for bespoke hiring. Singh *et al*., (2020) [30].
3. Climate Resilience Building Among Farmers Through Crop Residue Management Project for Punjab, Haryana, and Rajasthan with Rs. 549.38 Crores over 3 years and 3 months Lowering GHG emissions, developing implementable and sustainable entrepreneurial models in rural regions, and identifying potential co-benefits and policy interventions are the goals. Moef (2018) [22]
4. Farmers can rent residue management machinery and tools from village-level Farm Machinery Banks or Custom Hiring Centres, such as a Happy Seeder, a Rotavator, a Zero till Seed Drill, a Straw Baler, a Paddy Straw Chopper/ Mulcher, a Gyro Rake, a Straw Reaper, a Shredder, and so on. Birla *et al*., (2020) [6].
5. The Punjab government issued a 'New and Renewable Sources of Energy Policy' in 2012 to encourage renewable energy in the province. By 2022, a capacity target of 600 megawatts from biomass and 500 megawatts from cogeneration has been set under this programme. Datta *et al*., (2017).
6. Haryana bioenergy policy launched by the Haryana government in 2018 to operate its excess crop residues to create bio-CNG/bio-manure/biofuel. Datta *et al*., (2017).

Conclusion

In Indian agriculture crop residue utilisation has huge potential. The farmers following conventional agriculture burning crop residue and becoming reason for environmental pollution. This review paper emphasizes the management strategies of crop residue management with crop residue incorporation, crop residue retention. Any management option has its own set of benefits and drawbacks. The area, soil, and condition can now determine the practise to be used. When crop residues are added to the soil, they increase the organic carbon content and the organic matter. The fertility and productivity of the soil are increased as the nutrient content of the soil increases. future research is needed on in-situ application of crop residue which is economically viable.

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